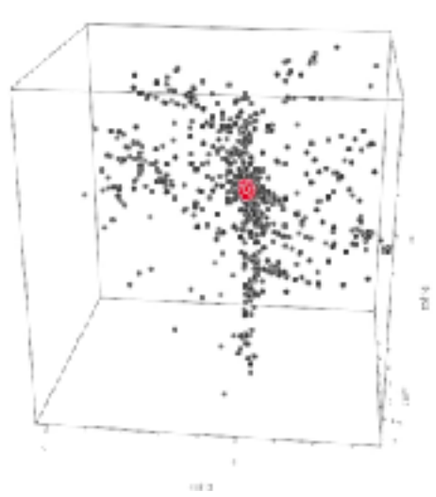
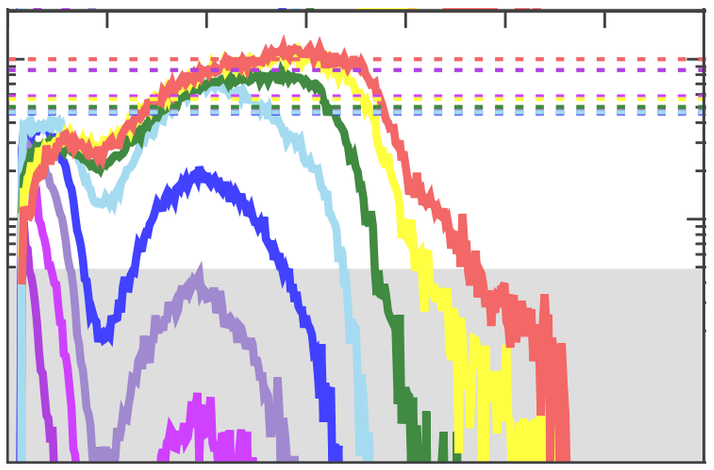
Using Stellar Archaeology and Pair-Instability Supernovae to Detect the First Stars

Tilman Hartwig

Naoki Yoshida, Mattis Magg, Anna Frebel, Simon Glover, Facundo Gómez, Brendan Griffen, Miho Ishigaki, Alex Ji, Ralf Klessen, Brian O'Shea, Nozomu Tominaga, Volker Bromm, Avi Loeb

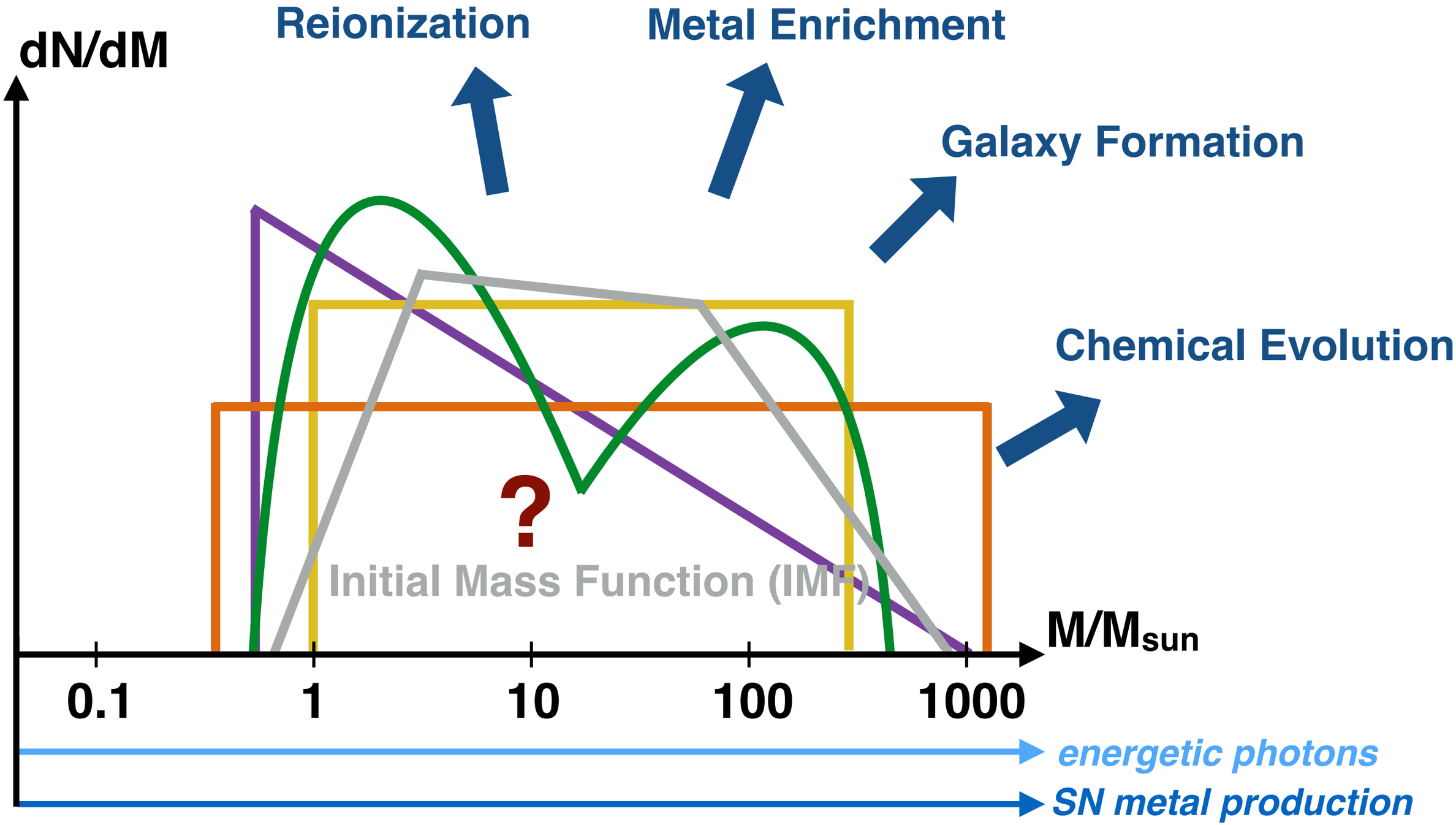




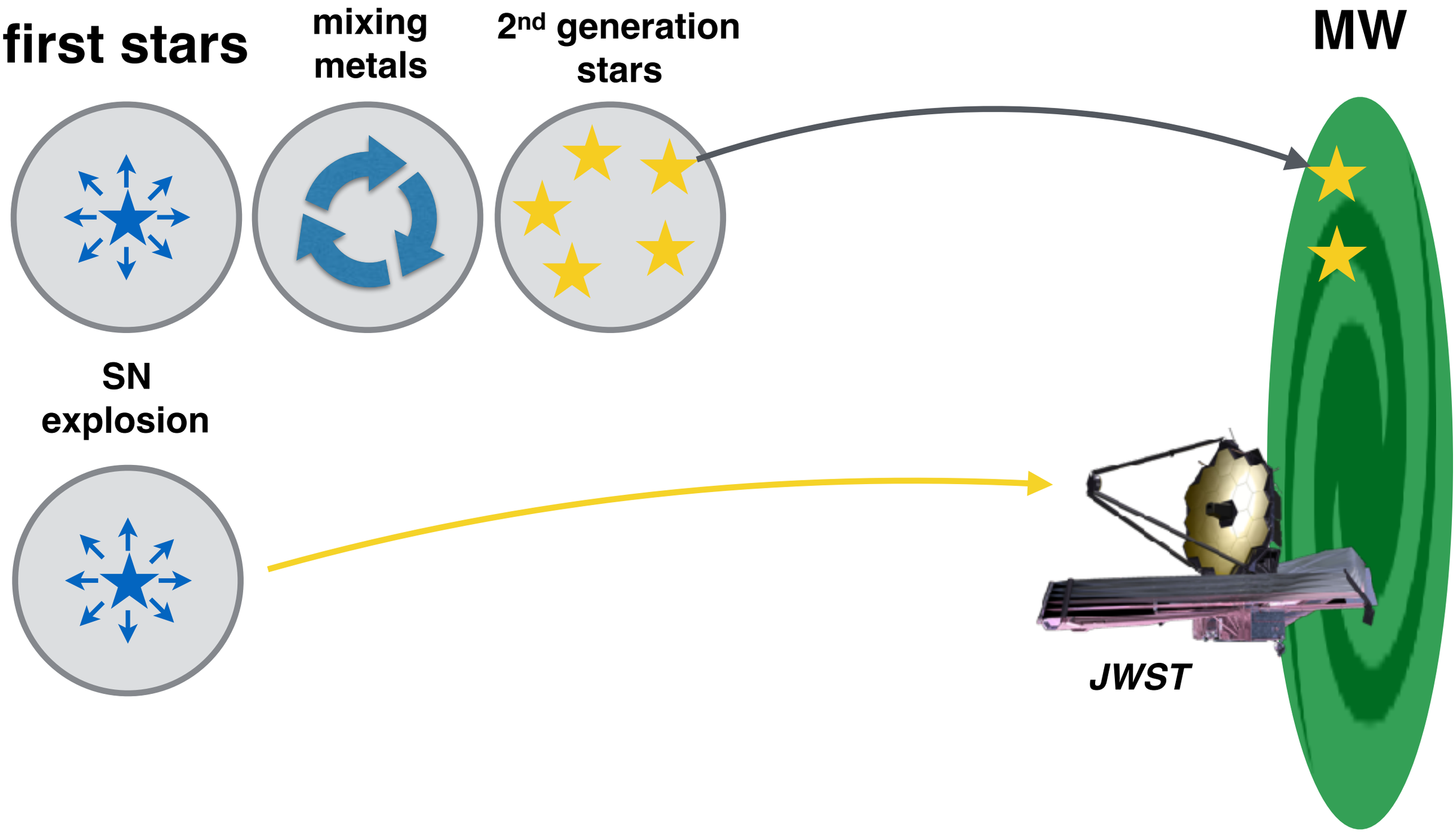
THE UNIVERSITY OF TOKYO

Kure - February, 11th

The first stars set the scene



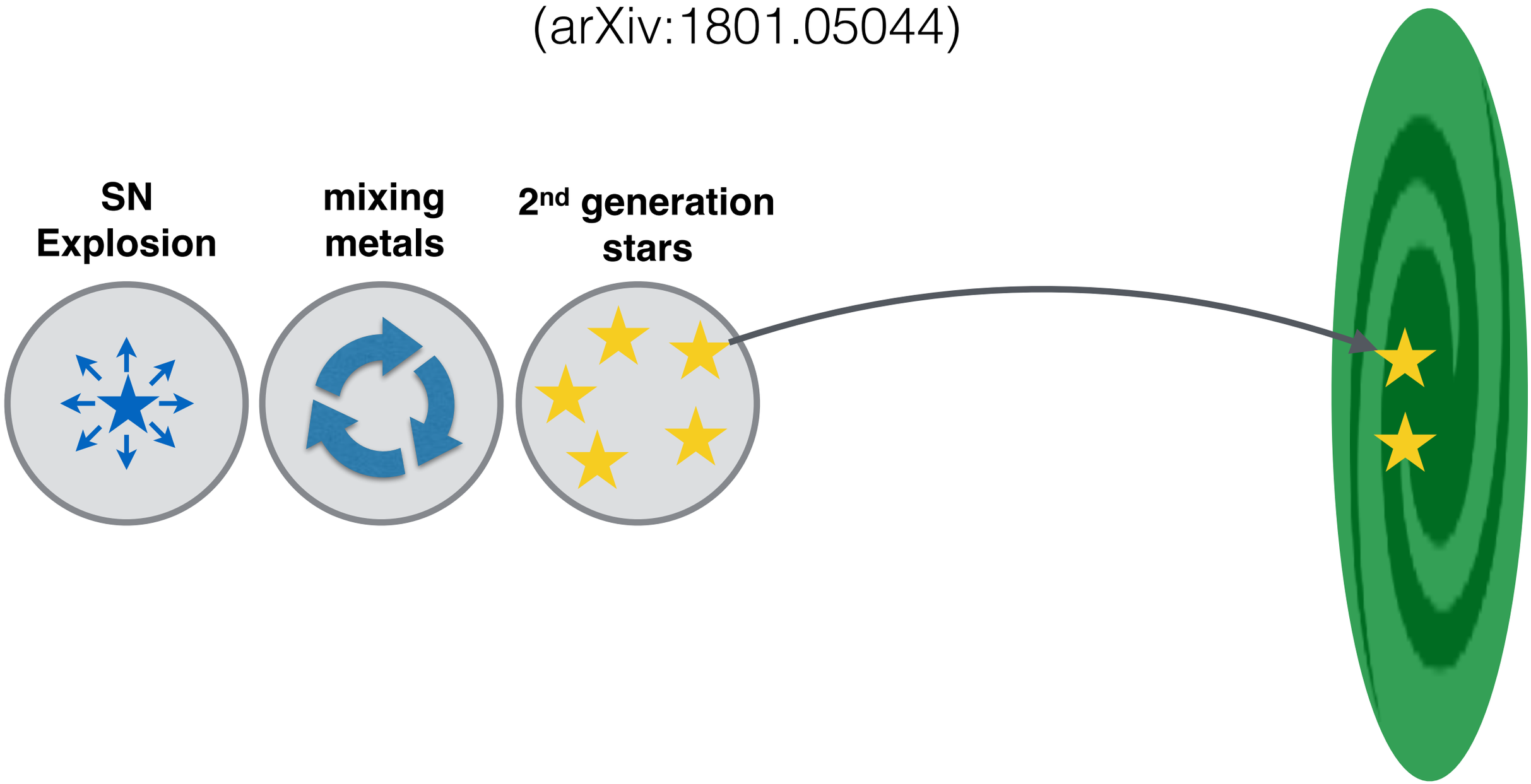
Observing the First Stars



Observing the First Stars

...with Stellar Archaeology

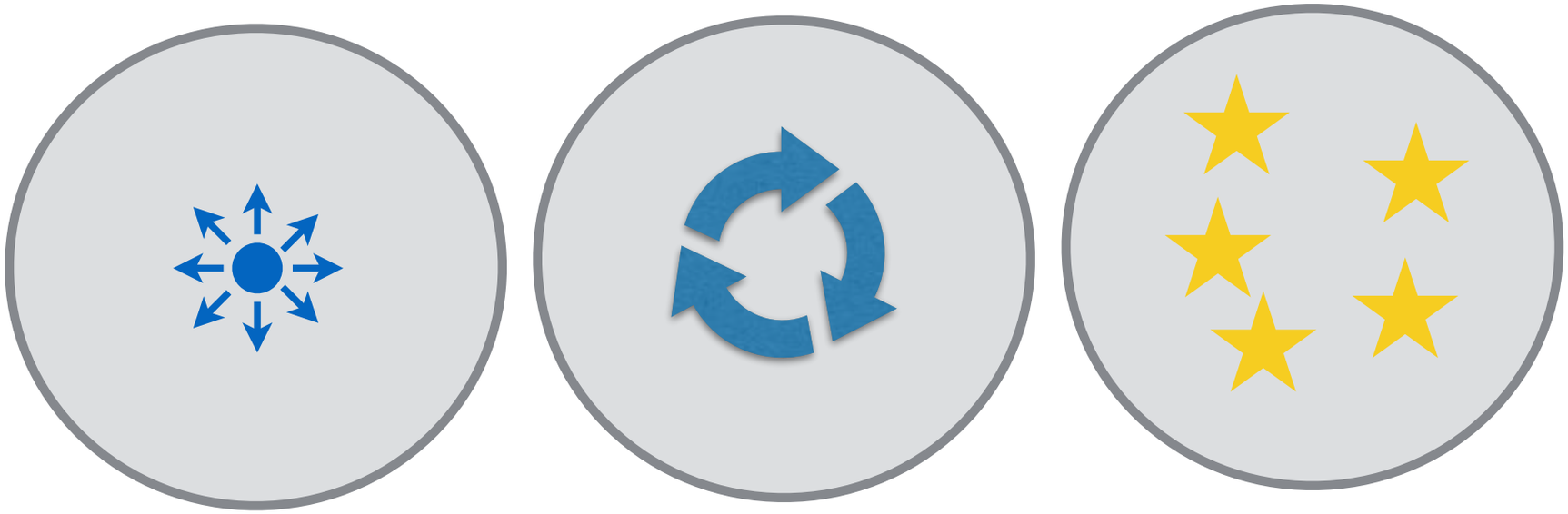
(arXiv:1801.05044)



Star formation after the first SNe

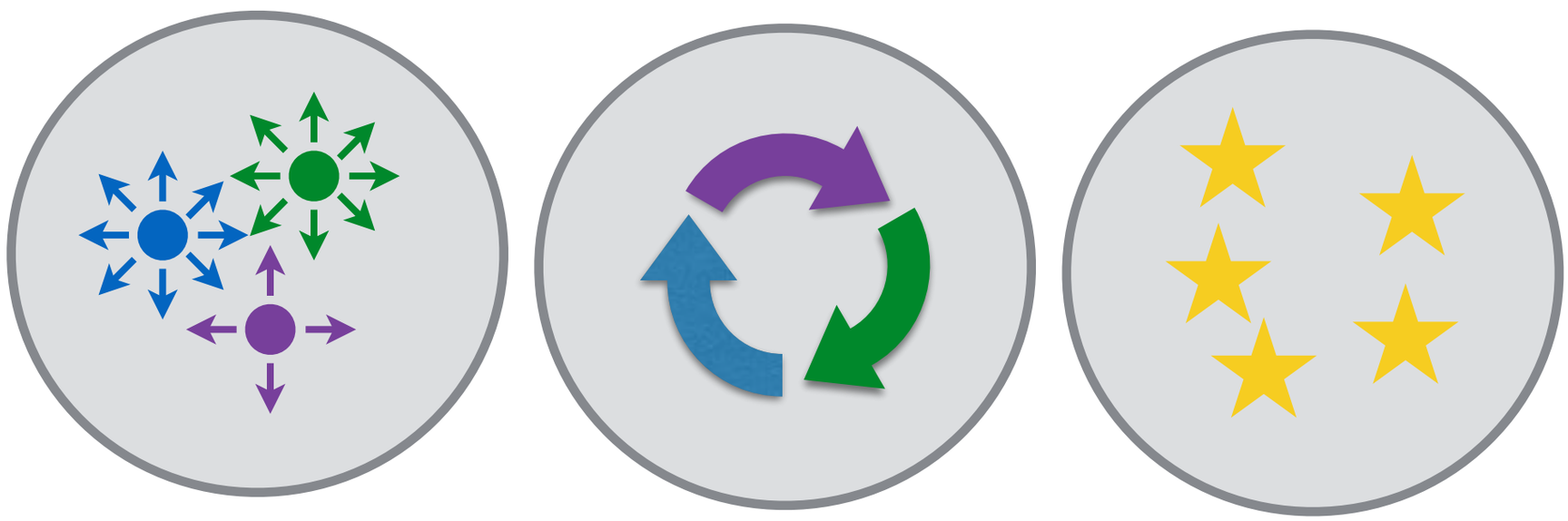
first stars | mixing | 2nd generation stars

one supernova



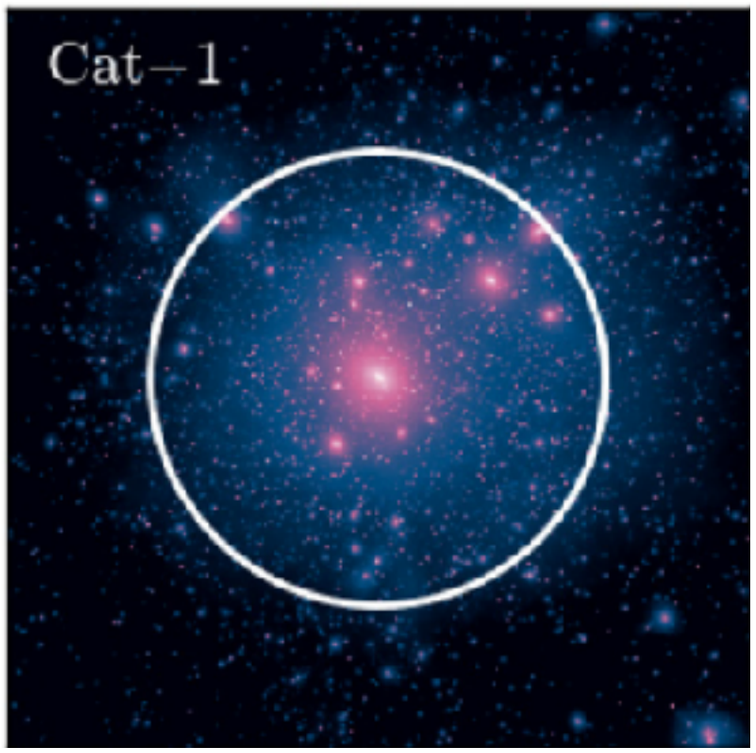
→ constrain progenitor mass

multiple supernovae

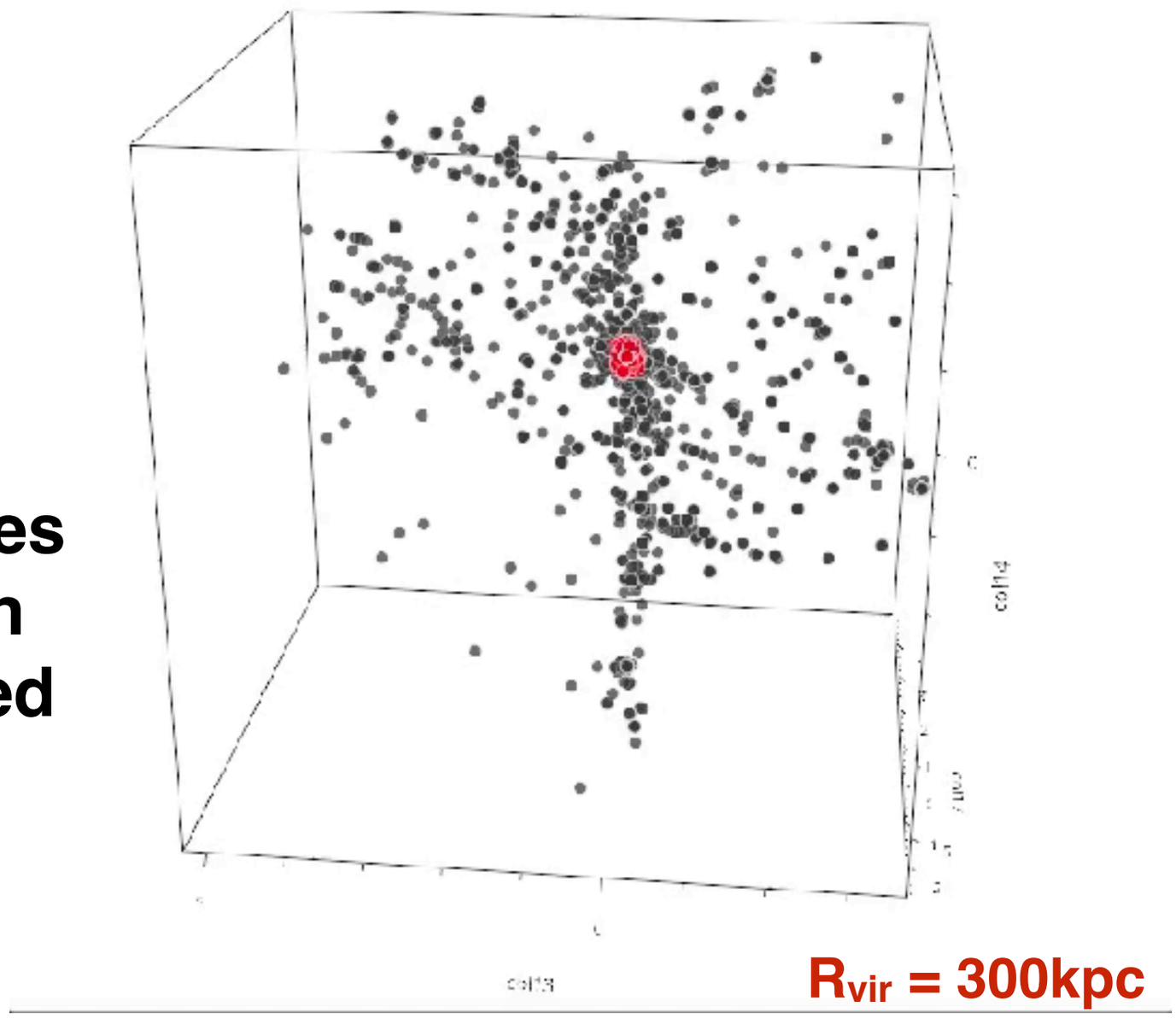


→ constrain progenitor masses?

Semi-analytical model of Pop III star formation



Griffen+16



- **30 MW-like DM merger trees from Caterpillar simulation**
- **Pop III star formation based on Hartwig+15b, Magg+18**
- **Chemical yields from Nomoto+13**

R_{vir} = 300kpc

Methodology

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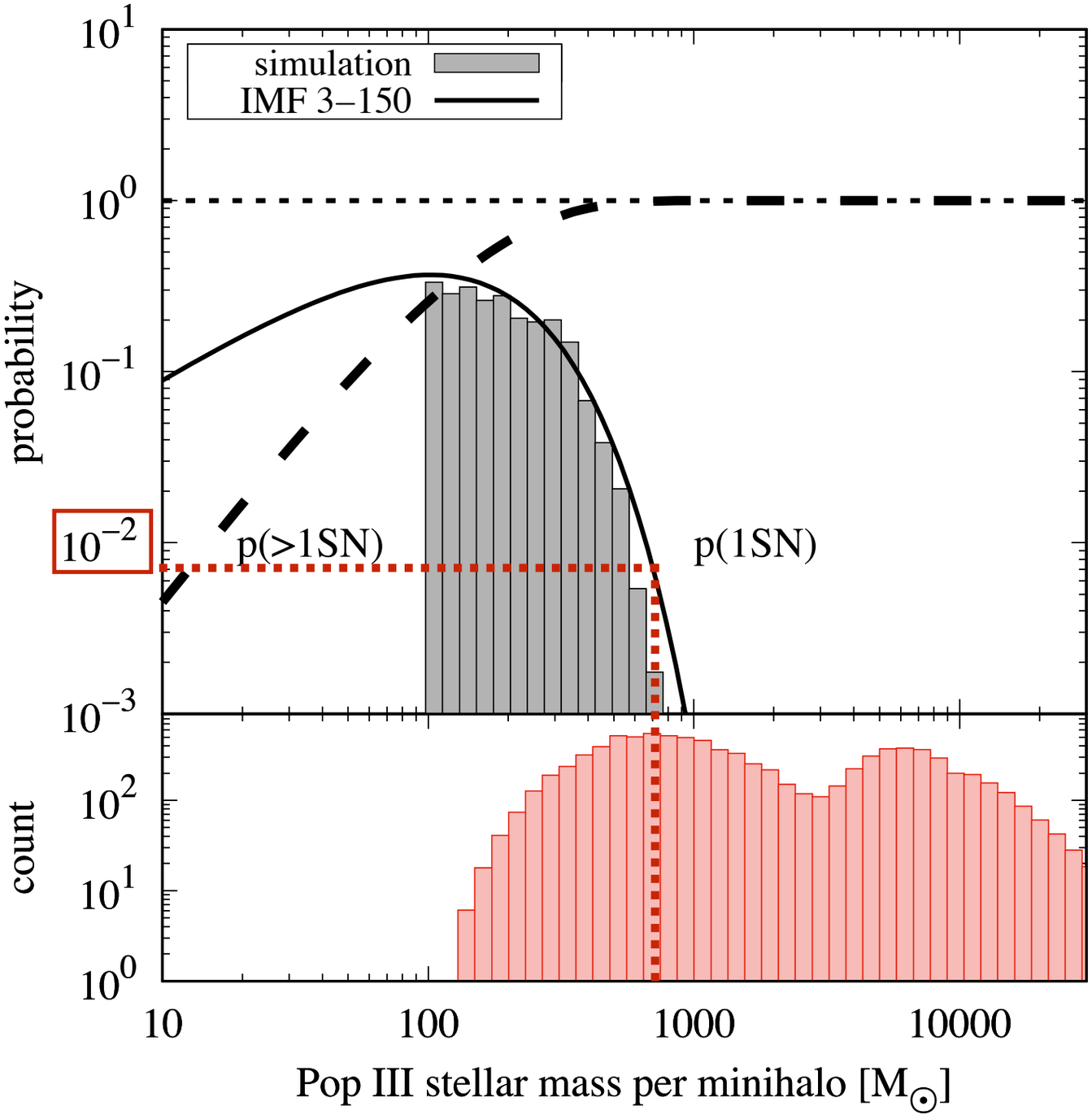
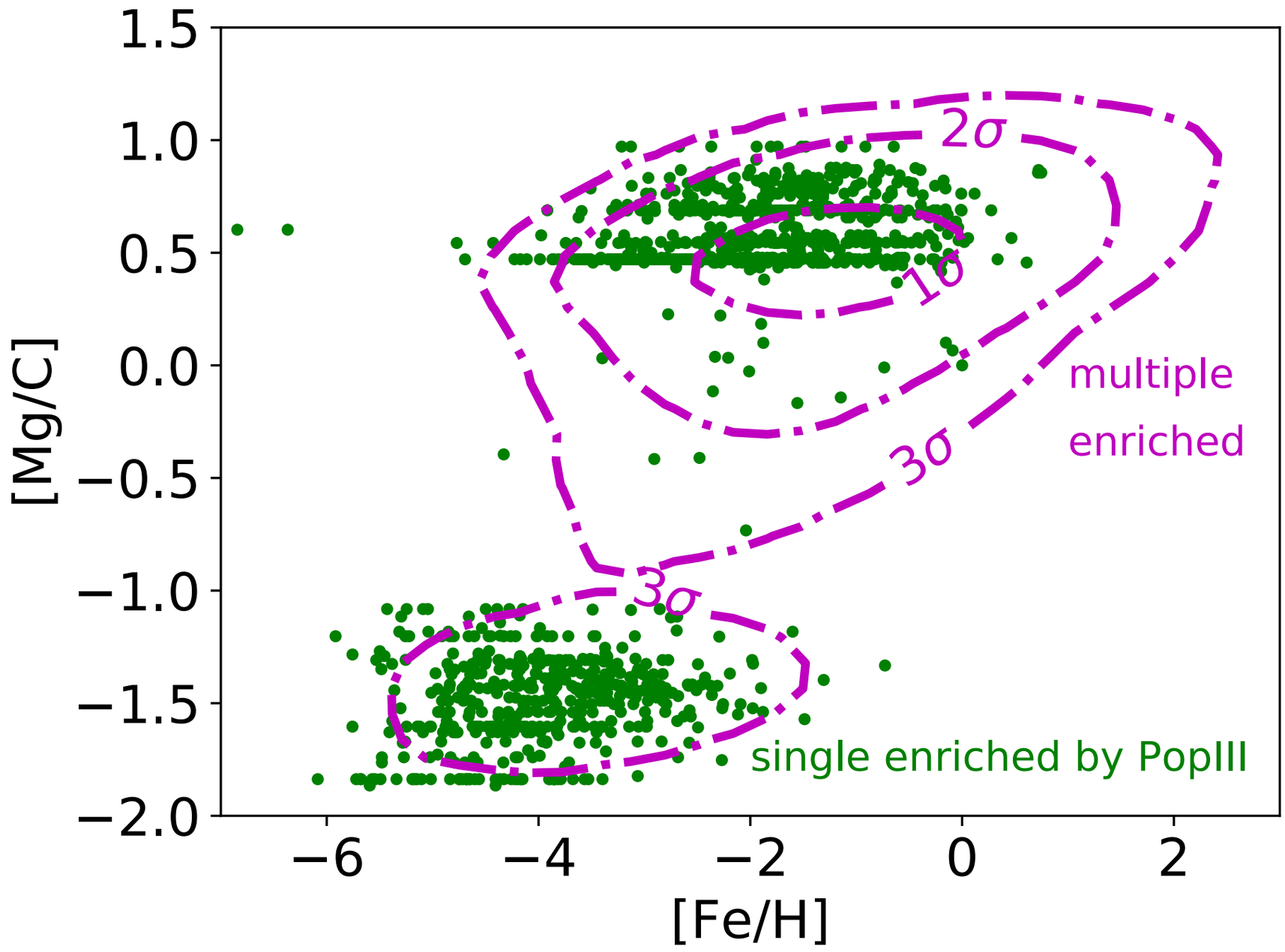
Probability of 1SN per halo



- **Poisson statistics with on average one SN per 100M_{sun} of stellar mass**
- **Single-enriched 2nd generation stars only in one out of 100 halos.**

Results **Tilman Hartwig**

Single-enriched 2nd generation stars occupy specific regions in the chemical plane



Results

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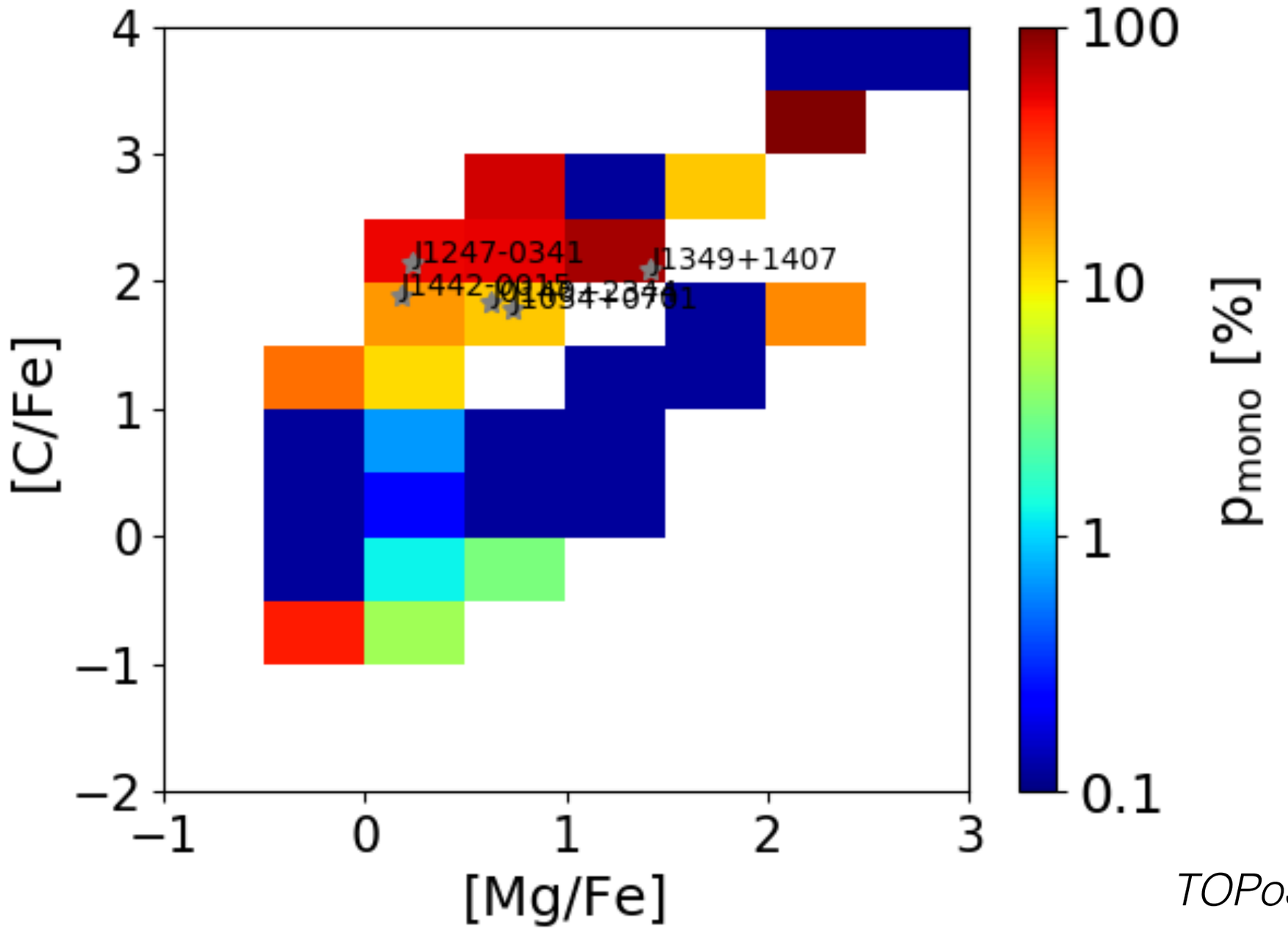
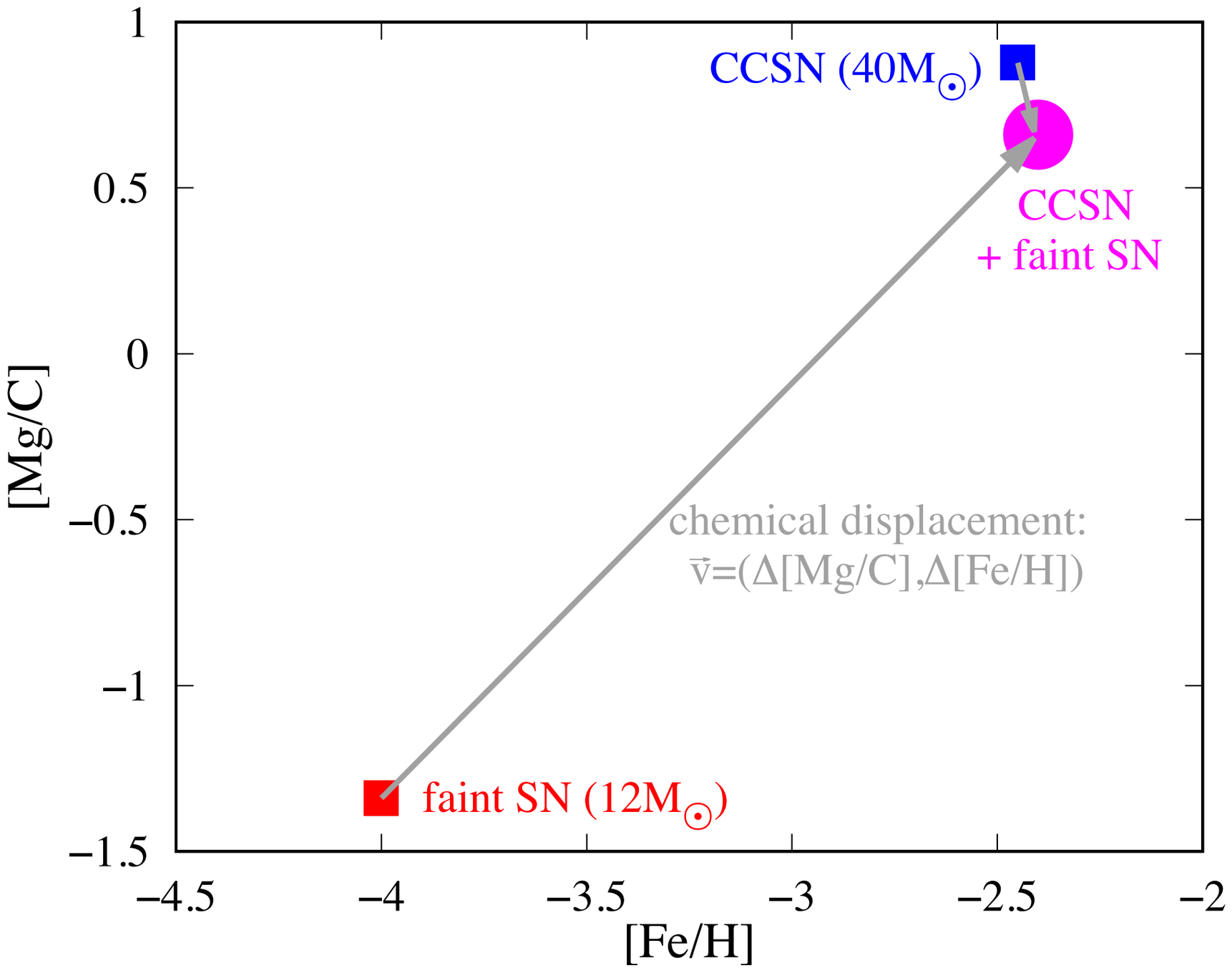
Probability to find single-enriched 2nd generation stars



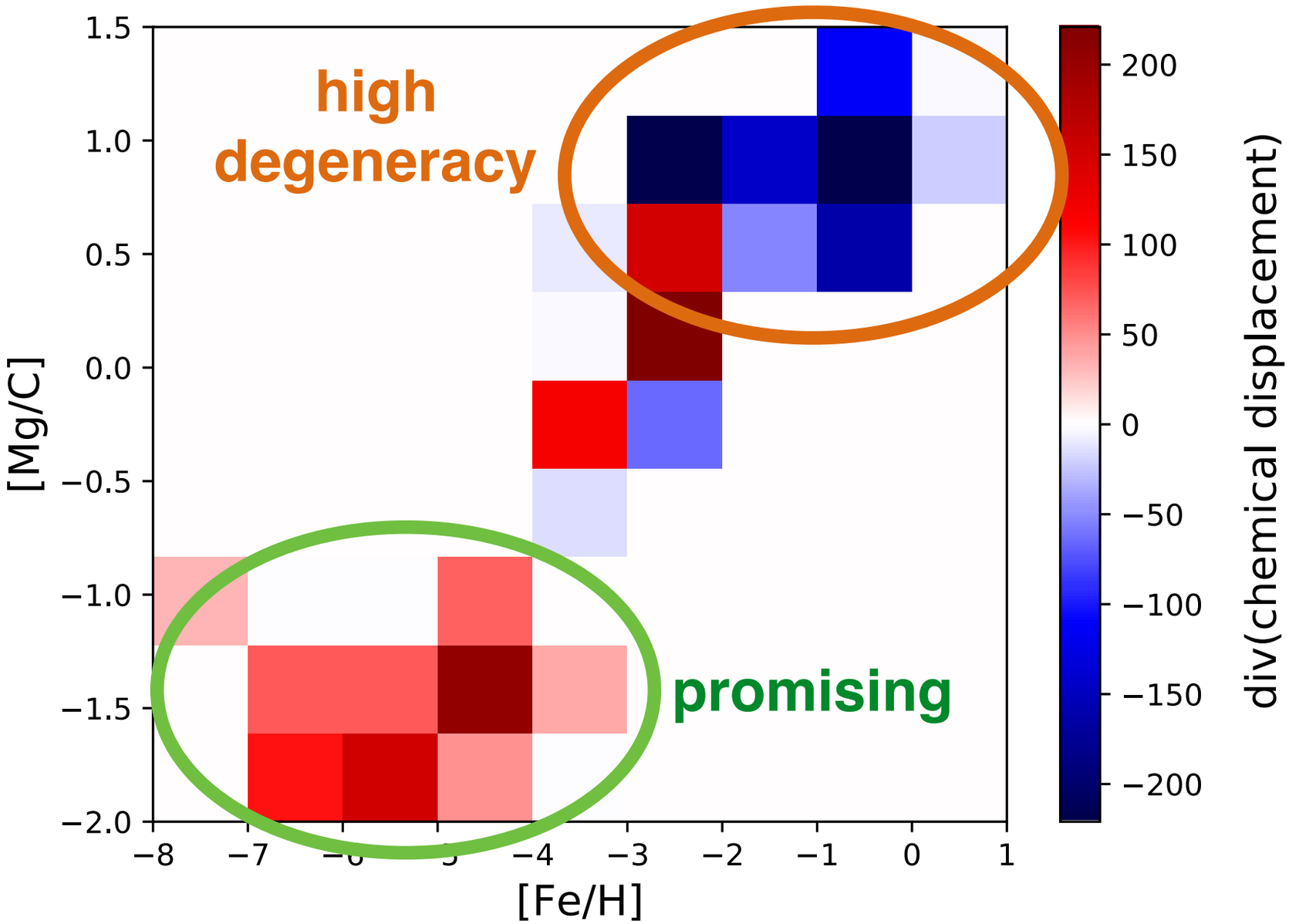
TOPoS Survey

Results **Tilman Hartwig**

Illustrate PopIII SN yields in chemical plane: "chemical displacement"



Novel diagnostic to identify single-enriched 2nd generation stars: Divergence of the chemical displacement



- Computationally cheap
- Depends only on SN yields
- Other element ratios provide additional information

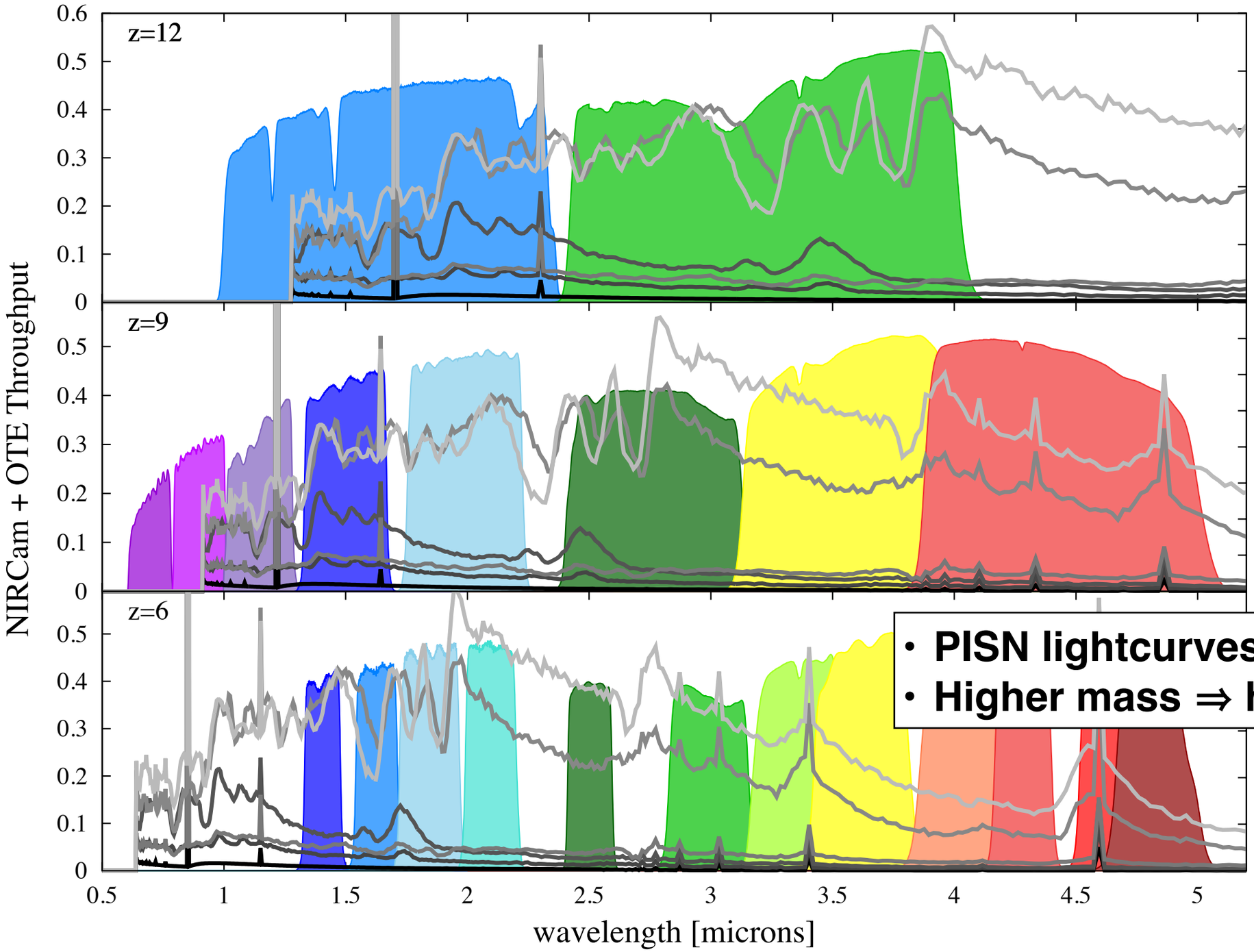
Results **Tilman Hartwig**

Observing the First Stars

...with JWST

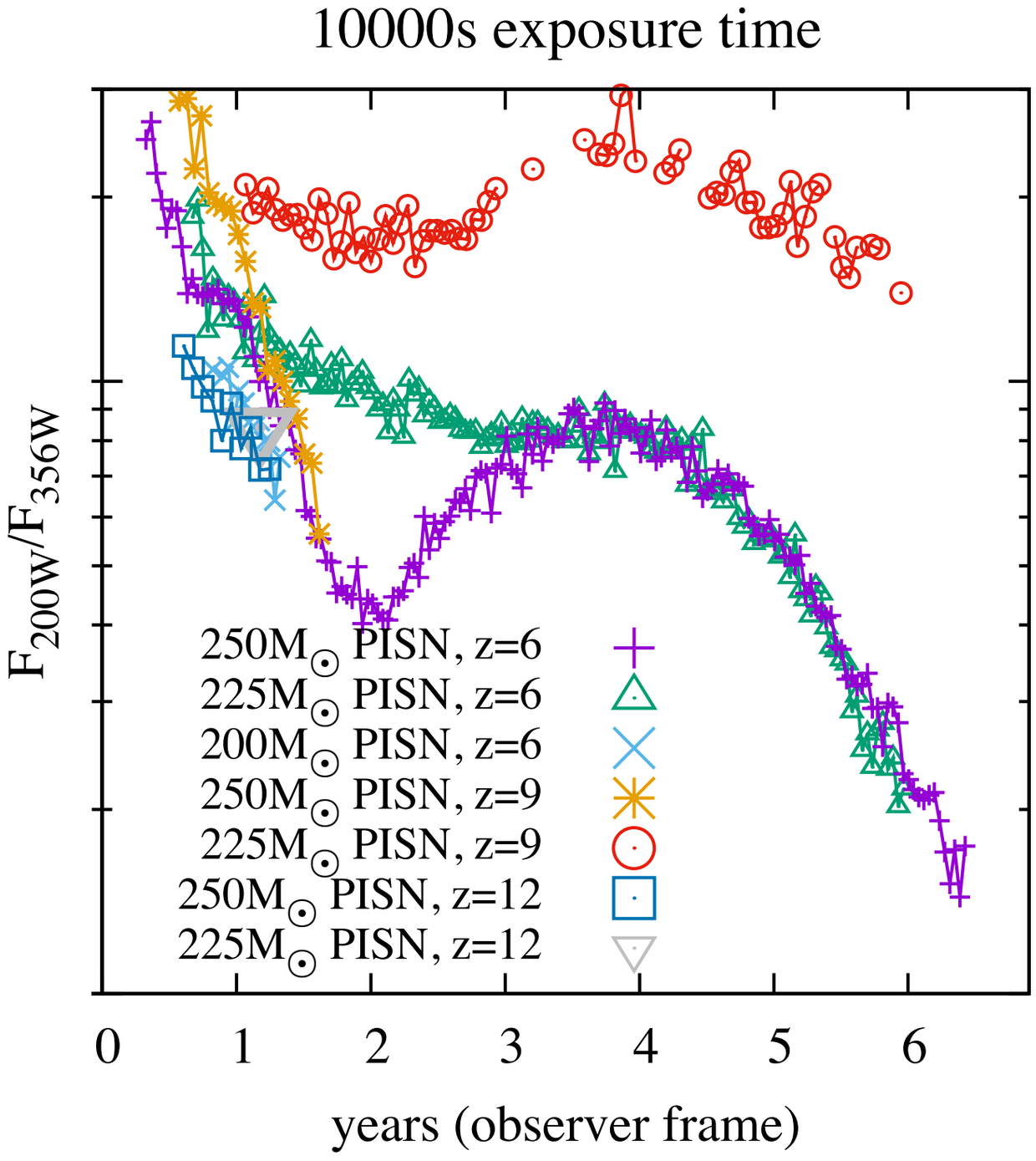
(arXiv:1711.05742)

NIRcam filters are well suited



- PISN lightcurves from Kasen+11
- Higher mass ⇒ higher luminosity

Lightcurves for a long exposure time



Visibility time depends on:

- **redshift**
- **progenitor mass**

Results

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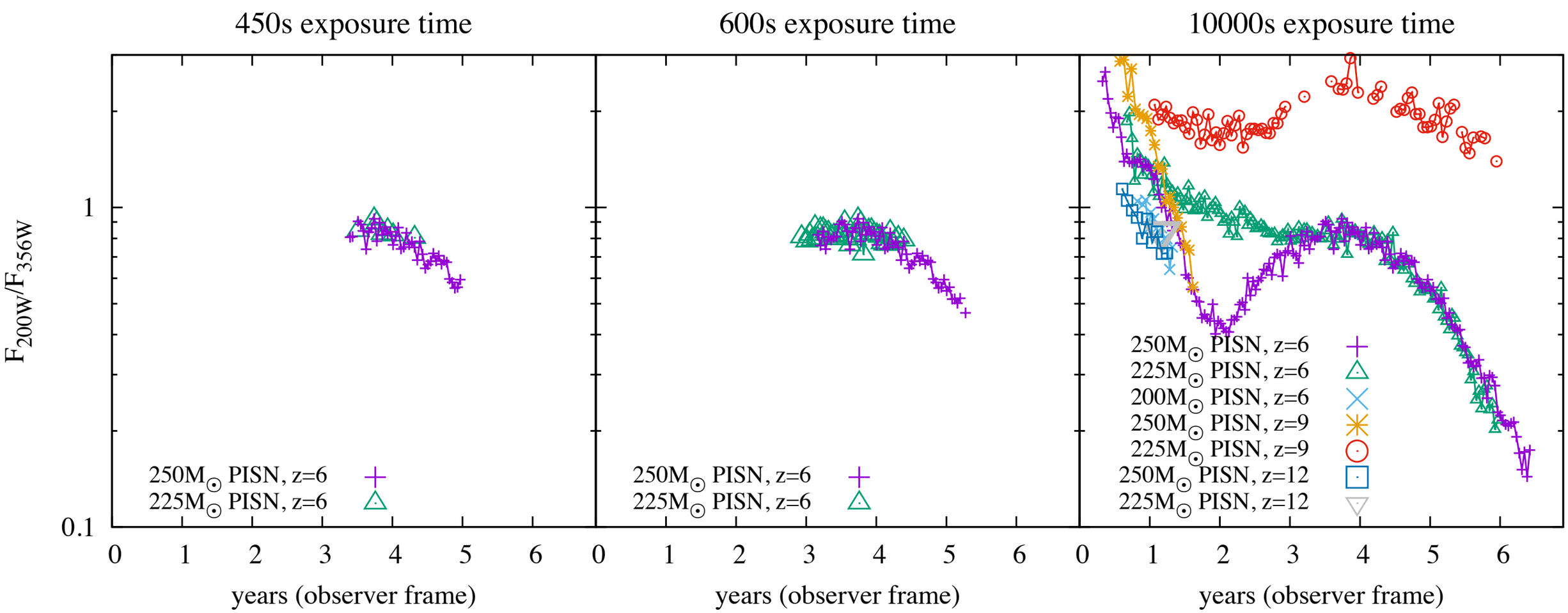
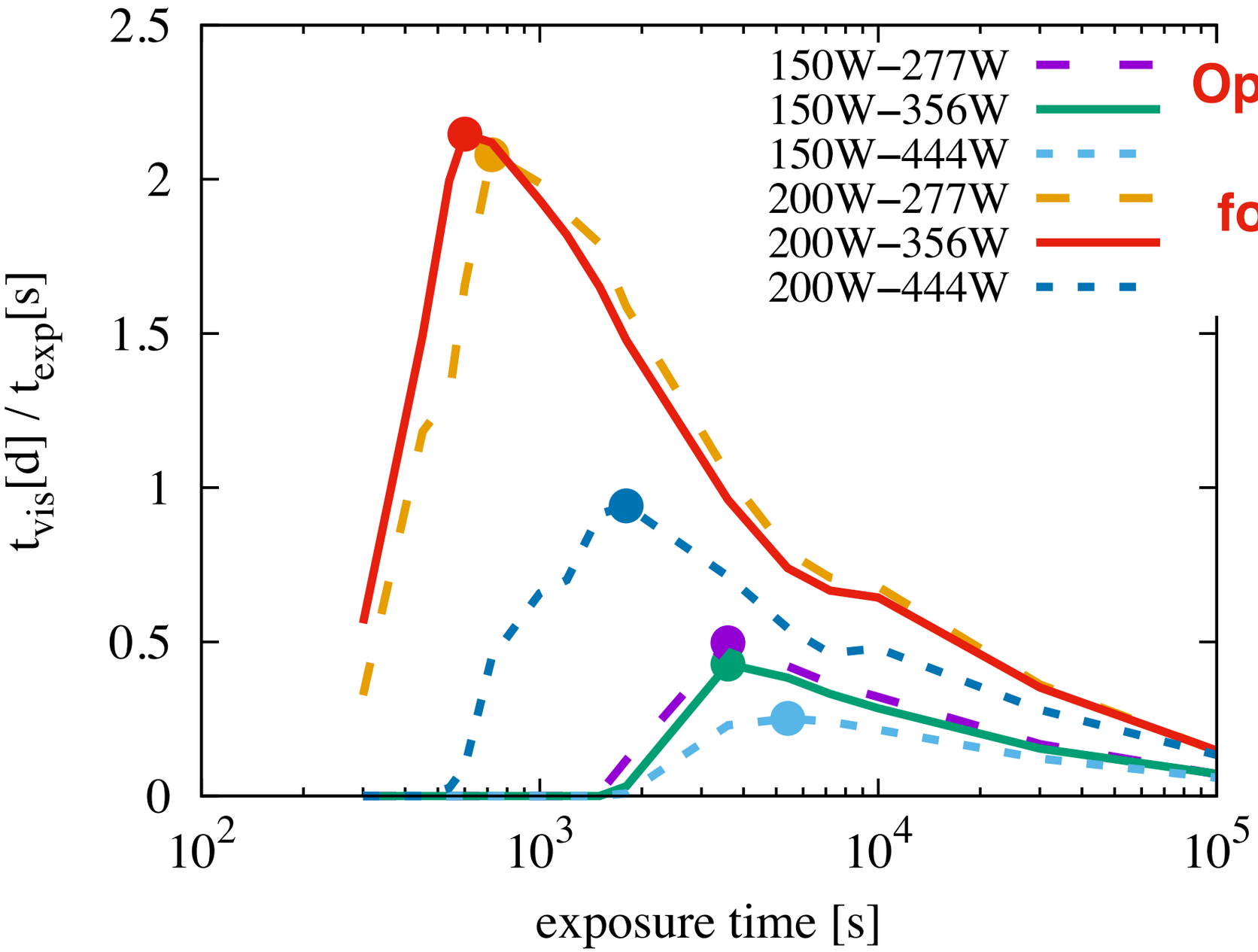
Lightcurves for different exposure times



More efficient to observe 10 field of view with t_{exp} = 600s each
or
observe 1 field of view with t_{exp} = 6000s?

Optimal Exposure Time and Filter Combination

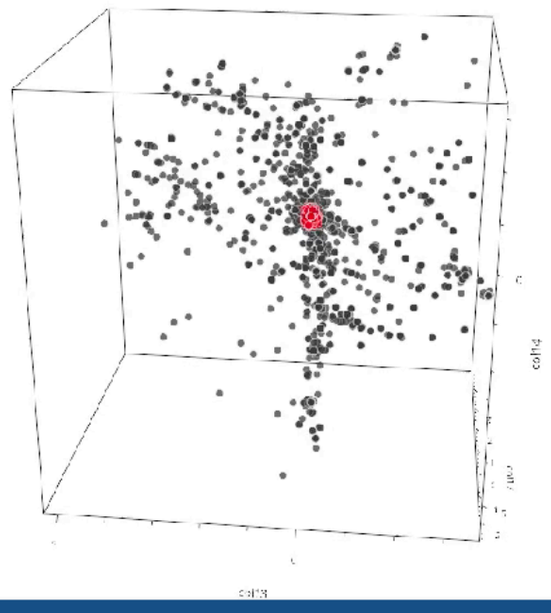


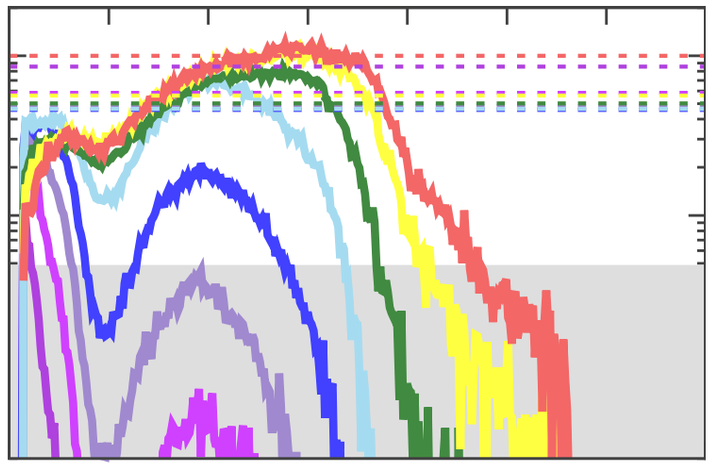
Optimal exposure time: t_{exp} = 600s for the F200W-F356W combination

Results **Tilman Hartwig**

Detecting the First Stars

- Stellar Archaeology is a powerful tool to derive the **masses of individual Pop III stars**
- New diagnostic to identify single-enriched 2nd generation stars (1% probability)
- PISNe are bright enough to be seen with JWST, but they are rare so that we need optimised survey strategies (50,000 FoV)
- (non-)detections with JWST will probe the **high-mass end** of the Pop III IMF
- Gravitational Waves will probe the **high-mass end** of the Pop III IMF over the next decade(s) (Hartwig+16,Kinugawa+16,Inayoshi+16)





Conclusion

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